

Land Subsidence and Groundwater Storage Change Assessment using InSAR and GRACE in the Arid Environment of Saudi Arabia

Prof. Dr. Mohamed Elhag

**Department of Water Resources, Faculty of Environmental Sciences, King Abdulaziz University,
Jeddah, 21589, Saudi Arabia**

**The State Key Laboratory, of Remote Sensing, Aerospace Information Institute, Chinese
Academy of Science, Beijing, 100101, China**

**Department of Geoinformation in Environmental Management, CI-HEAM/Mediterranean
Agronomic Institute of Chania, Chania 73100, Greece**

**Department of Applied Geosciences, Faculty of Science, German University of Technology in
Oman, Muscat, 1816, Oman**

Introduction

- To accurately quantify and analyze the extent of subsidence, the study performs the LiCSBAS package
- Long-term subsidence might occur due to terrestrial water storage (Δ TWS) change, which is also measured by Gravity Recovery and Climate Experiment (GRCAE) satellite data
- Combination of land subsidence and ground water storage change analysis was performed using LICSBAS-InSAR and groundwater storage anomalies (GWSA)

Study Area



Najran lies in the southwestern region of Saudi Arabia.

Location



Precambrian volcanic and sedimentary rock.

Geology



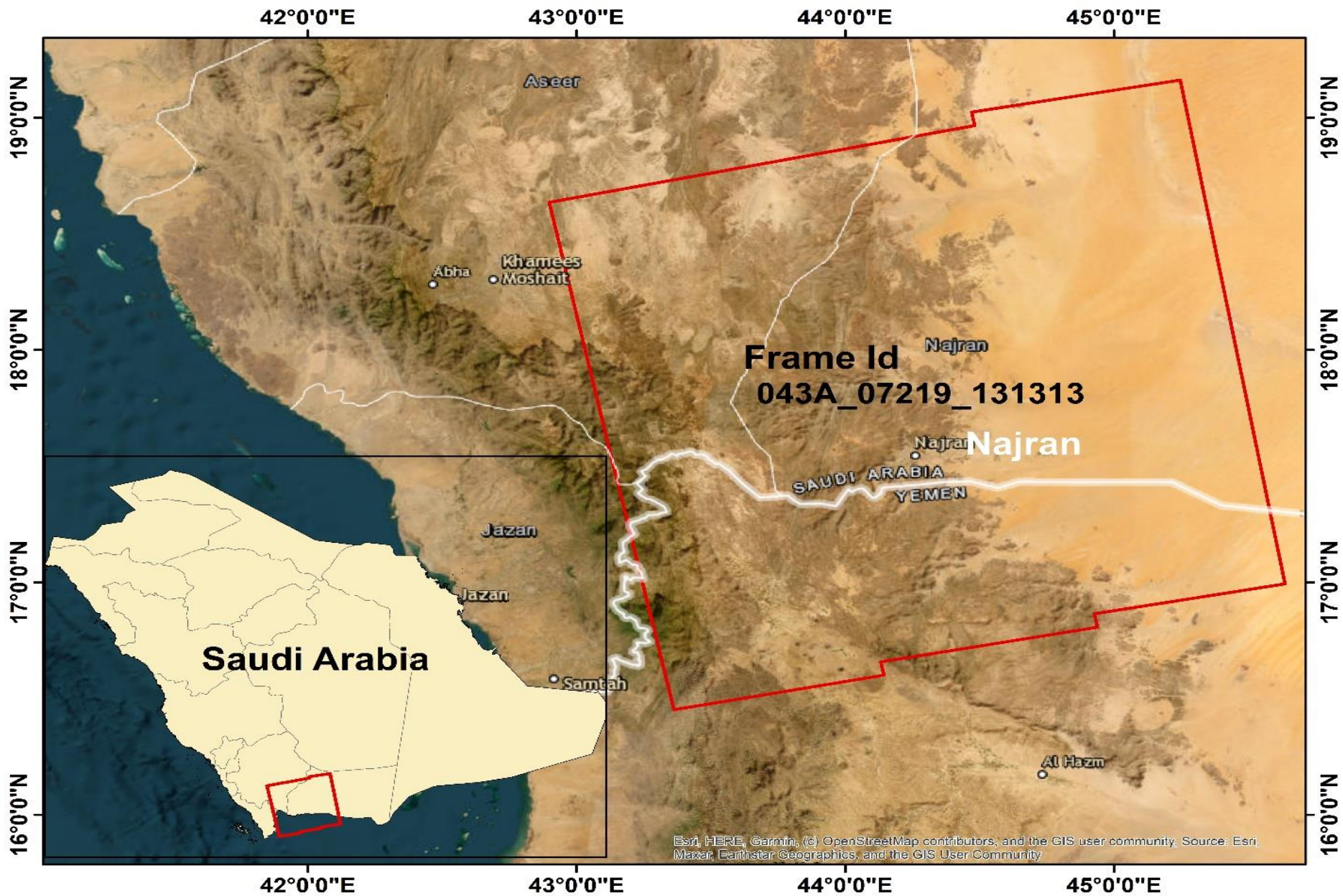
The N-S trending structures

Geologic structure



Arid and sub-arid climate with an average annual rainfall of 39 mm per year.

Climate



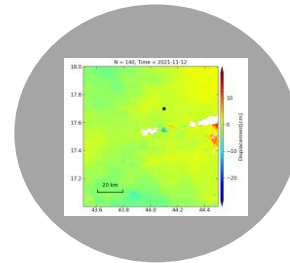
Methodology

Remote Sensing Observation



Passive sensing

Use natural source of energy



Active sensing

Radar, Lidar, SAR , InSAR

Radar measurements

01

Amplitude

- Strength of the signal
- Backscattering signal

02

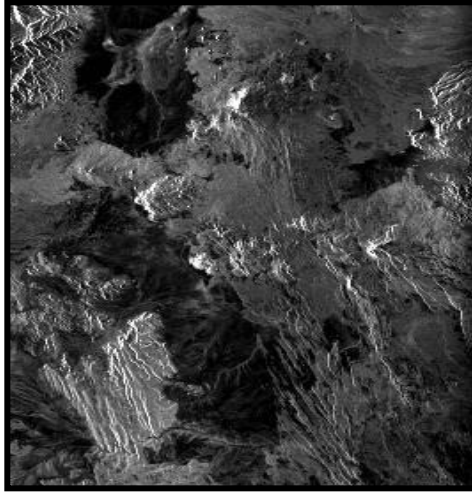
Phase

- Distance b/n satellite and target

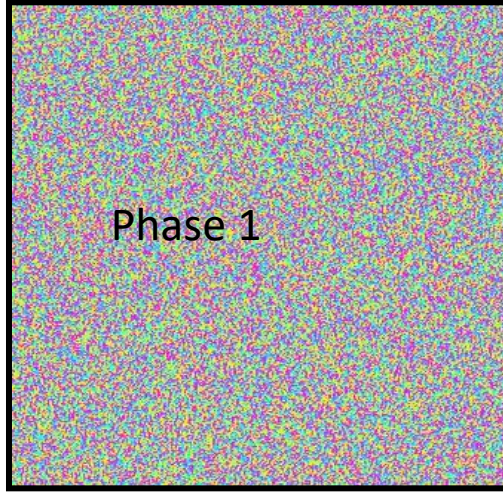
Interferometry Synthetic Aperture Radar (InSAR)

- Relies on interferometry, a technique that involves combining two or more radar images to extract information about the target area.
- The two SAR images are acquired at different times, creating a baseline.
- The phase difference between the two images is used to create an interferogram, which is a visual representation of the ground deformation.
- The interferogram is created by overlaying the two radar images and assigning colors to represent the phase difference.

Image 1: 17 July 2006



Amplitude



Phase

Phase 1 – Phase 2

= Interferogram

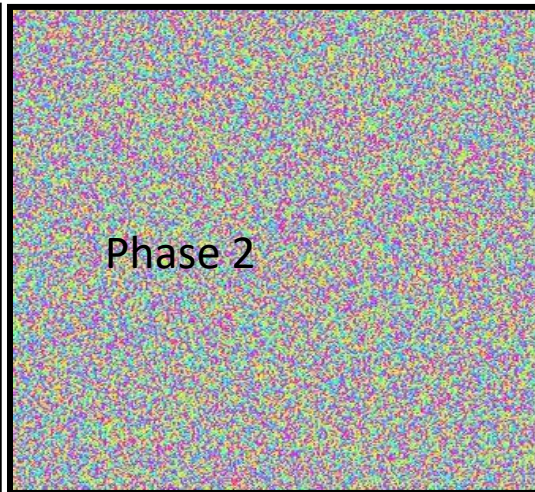
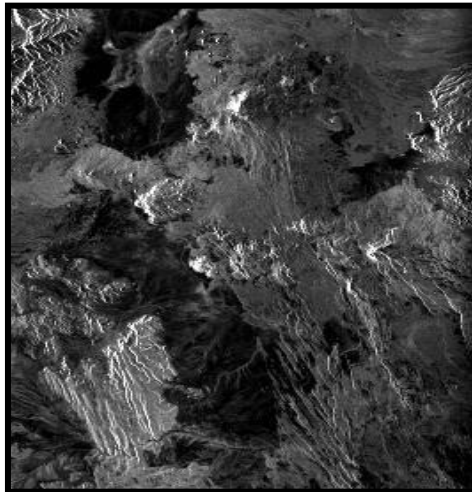
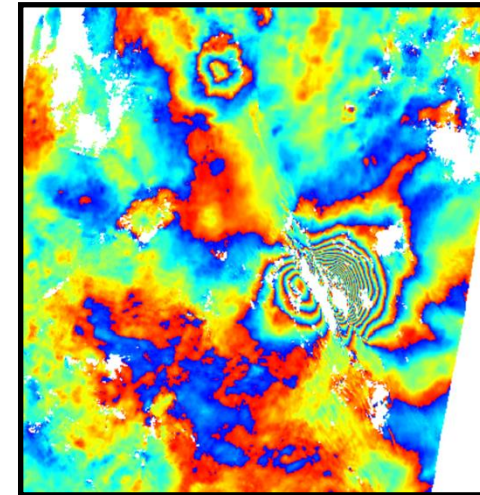


Image 2: 21 August 2006

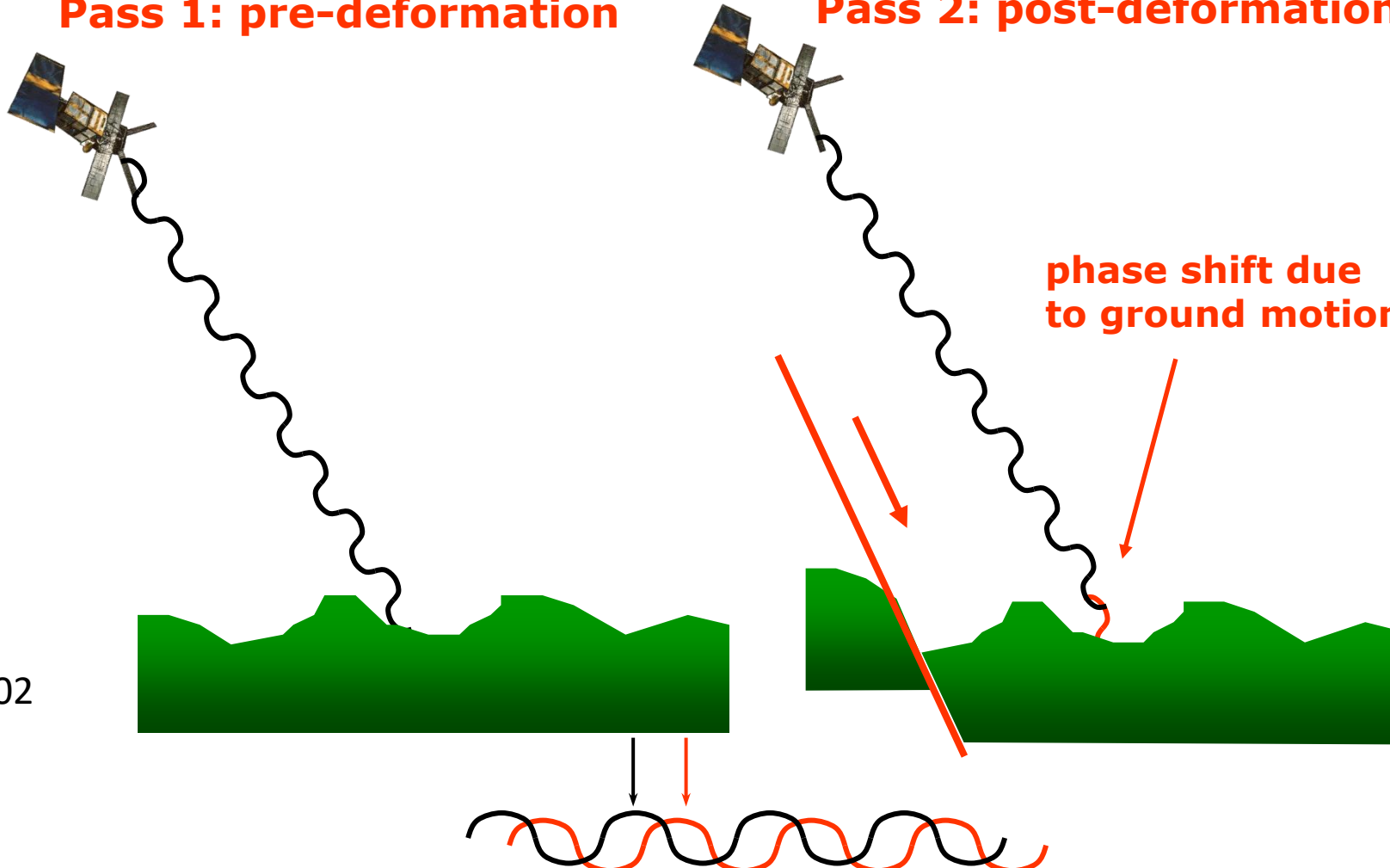
What contribute to the phase

$$\Delta\phi = \Delta\phi_{\text{def}} + \Delta\phi_{\text{geom}} + \Delta\phi_{\text{topo}} + \Delta\phi_{\text{atm}} + \Delta\phi_{\text{noise}}$$

$$\Delta\phi_{\text{def}} = \frac{4\pi}{\lambda} (\Delta d)$$

Pass 1: pre-deformation

Pass 2: post-deformation



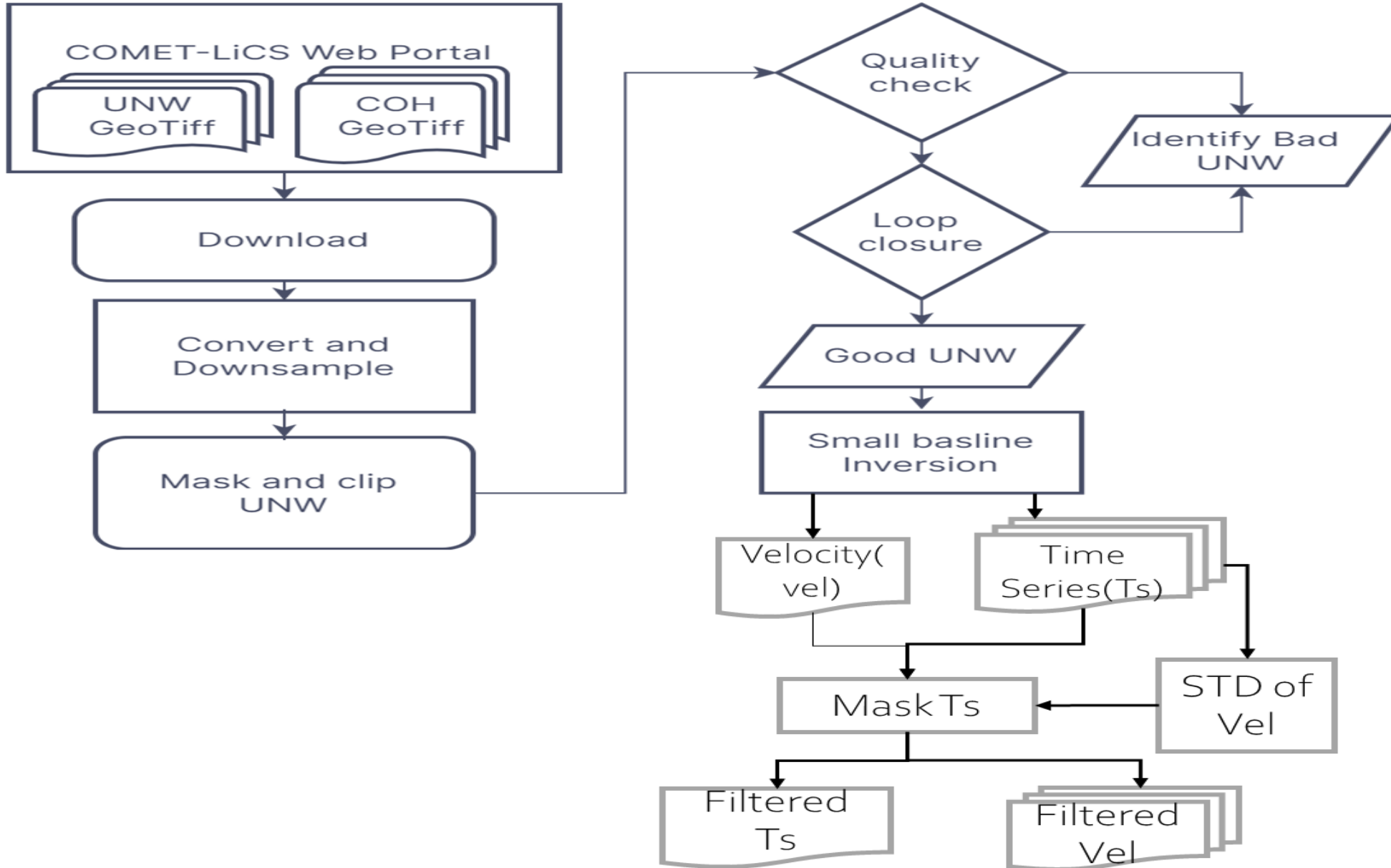
Wright, 2002

Manila, Philippines

United Nations / Philippines Workshop on the
Applications of Global Navigation Satellite Systems

22 – 26 April 2024

LiCSBAS Flow chart



GRACE

- Estimating Terrestrial Water Storage Anomalies (TWSA)
- GRACE observes changes in the earth's gravity field
- GRACE provides a measure of changes in the terrestrial water storage which refers to the sum of soil moisture, groundwater, surface water (water in surface bodies such as reservoirs, lakes, and rivers), snow water, and water in biomass

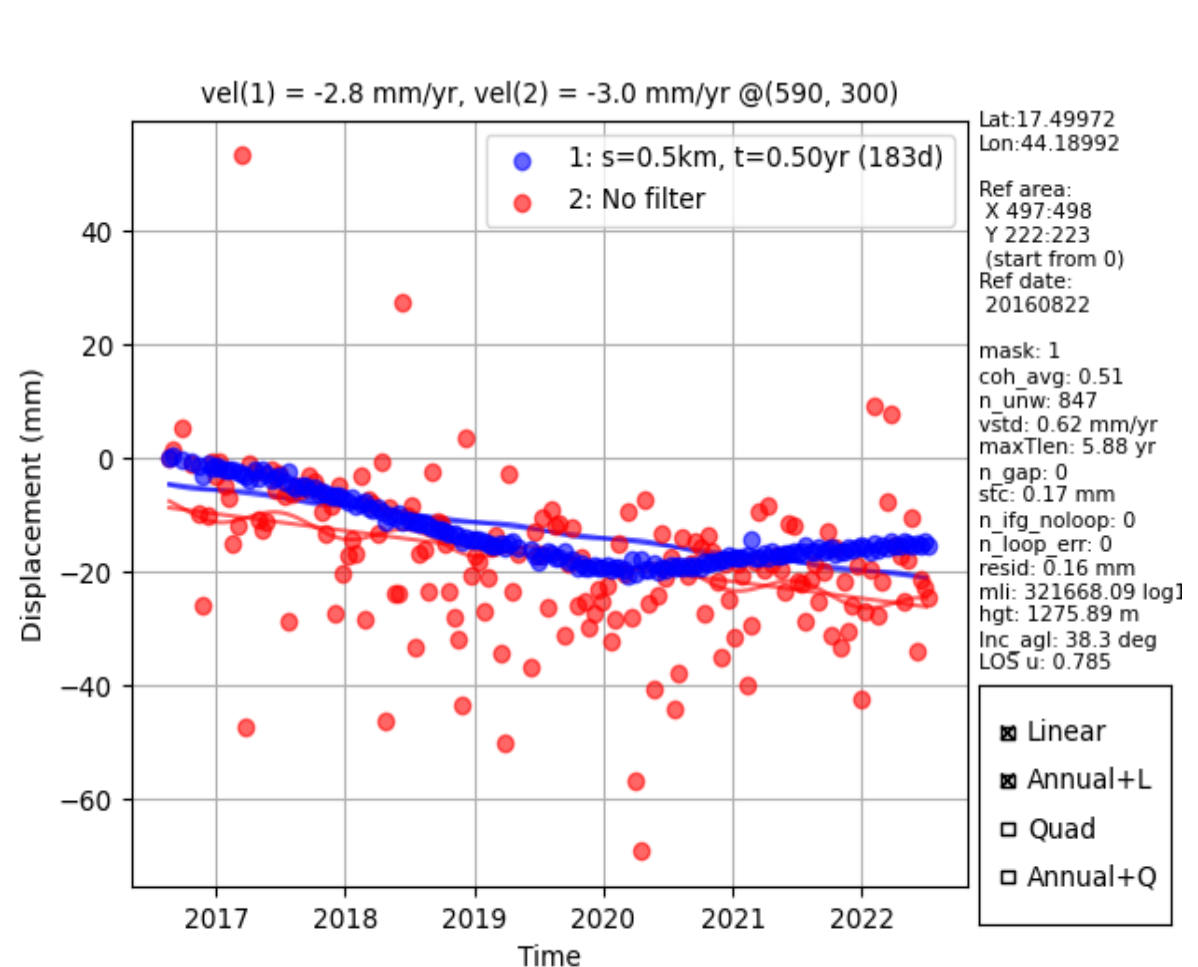
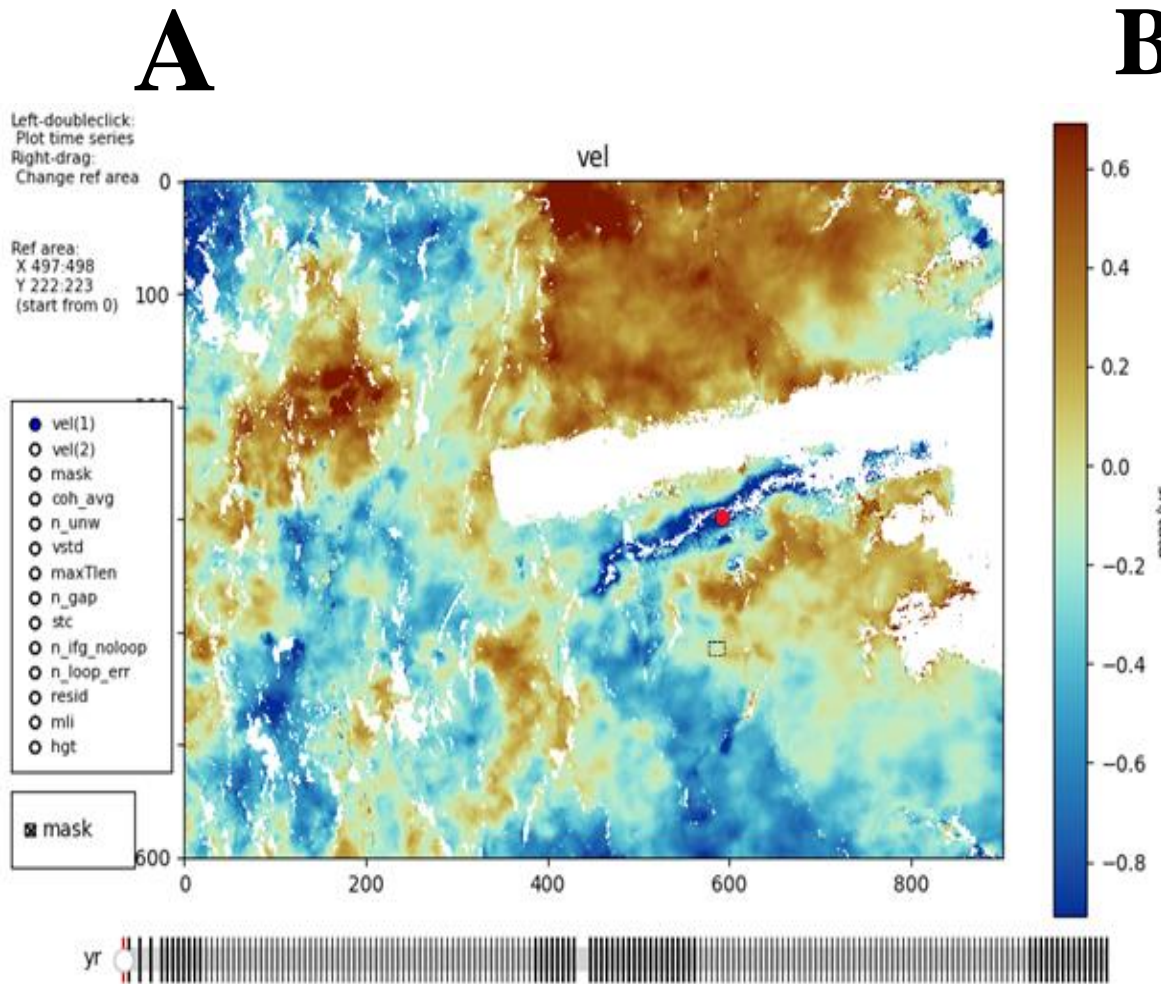
$$GWSA = TWSA - SMSA$$

- *GWSA* is groundwater storage anomalies, and *SMSA* is soil moisture anomalies

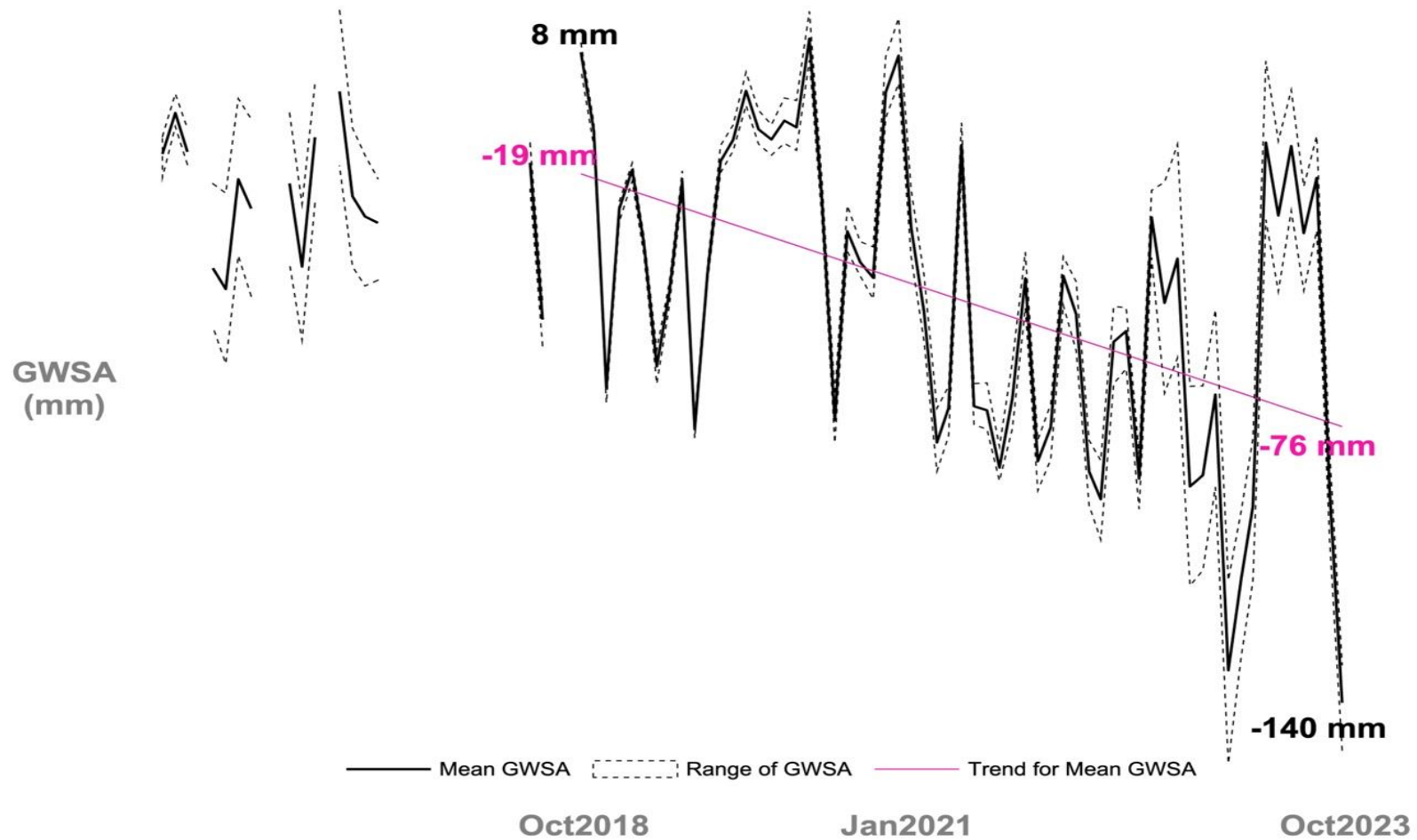
Results

LiCSBAS- InSAR

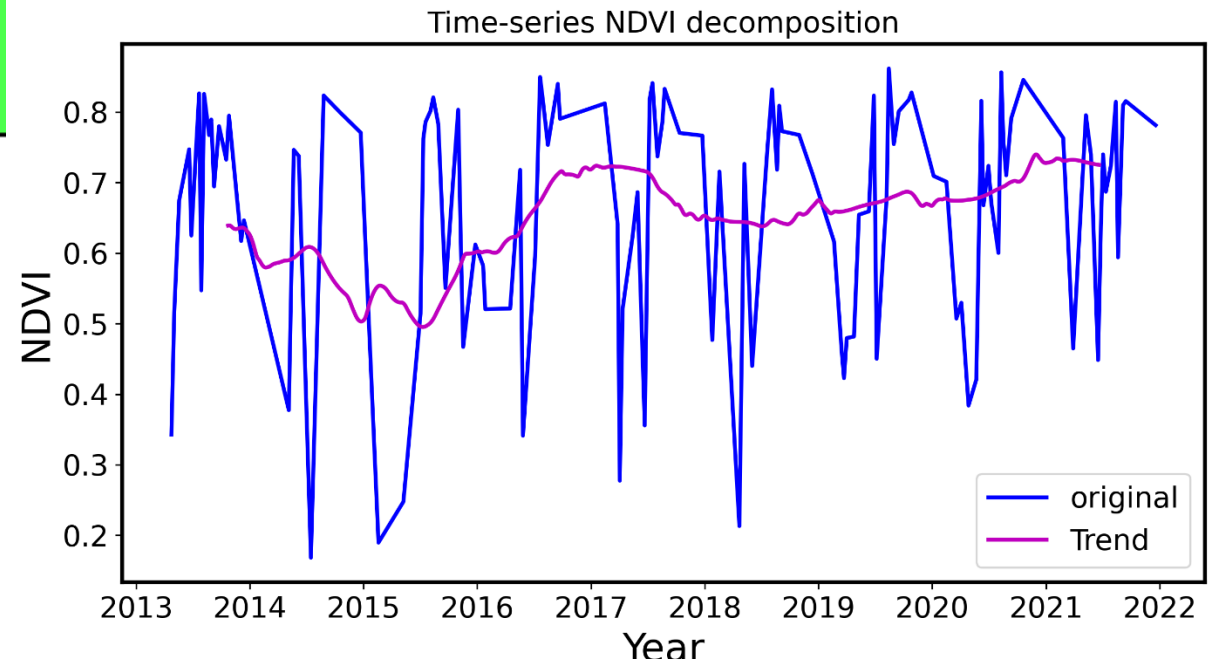
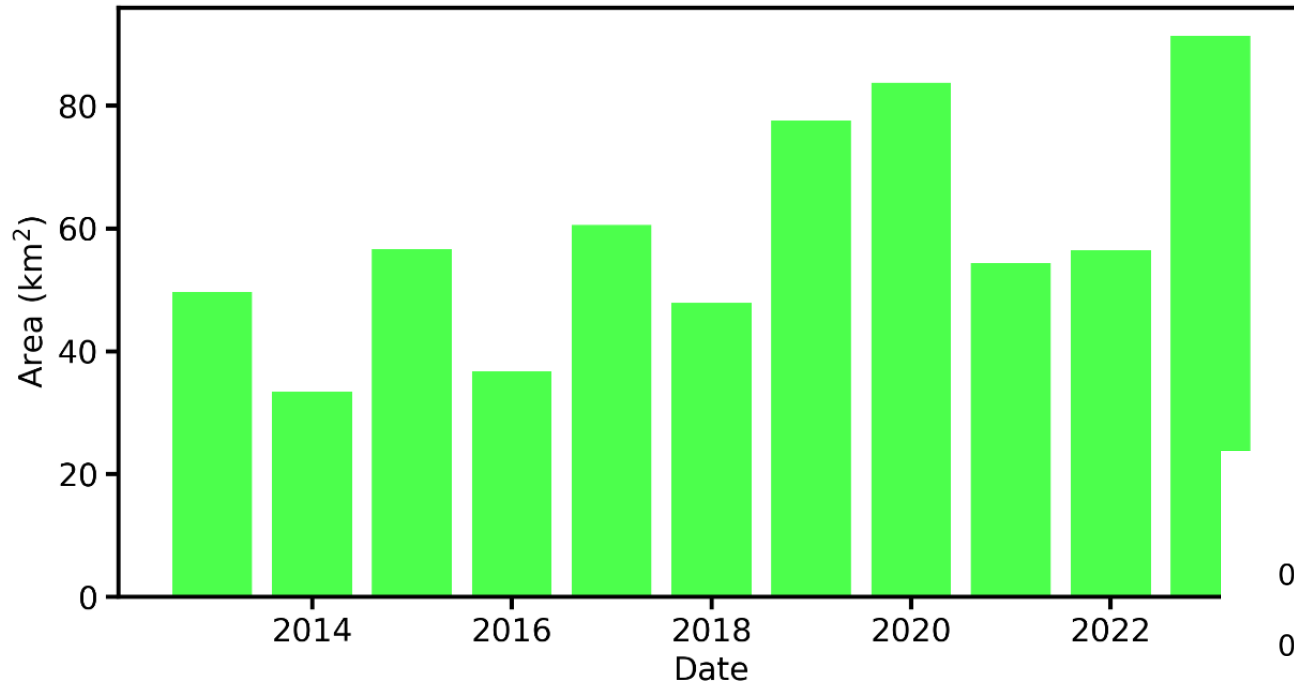
<https://github.com/yumorishita/LiCSBAS>



Groundwater storage anomalies (GWSA)



Vegetation change due to Extraction of GW water

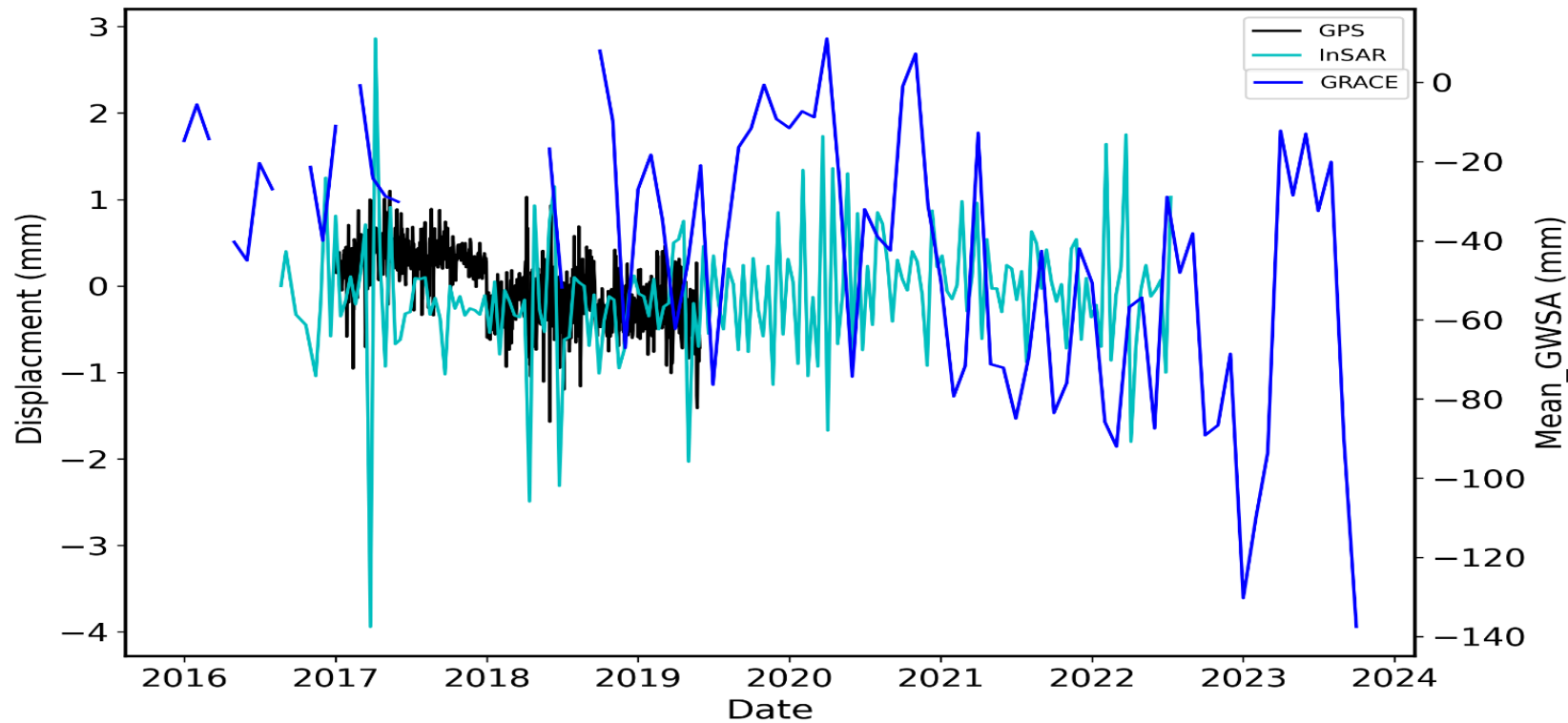


Validation

GNSS- Processed by GAMIT/GLOBK software

(<https://geoweb.mit.edu>)

15 cGPS +19 IGS station = 34



Conclusions

- LiCSBAS-InSAR has provided valuable insights into the subsidence
- Applying corrections, such as topographic, tropospheric delay, and phase ramps corrections,
- Subsidence rates in the region ranged between 0.2 and 0.6 cm per year
- The GRACE analysis showed that groundwater storage depleting at ~11.2 mm per year
- Validation was done by GNSS



IT IS THE AGE OF BIG DATA

Thanks for your attention

